Deployable Thermoelectric Metamaterial Energy Harvesting Monitoring System

Completed Technology Project (2014 - 2016)

Project Introduction

This project will combine a novel asynchronous monitoring system with the first-of-its-kind thermoelectric metamaterial. The thermoelectric prototype is constructed using bismuth telluride/copper and magnesium silicide/copper artificially anisotropic thermoelements, and it has an output voltage of 12 mV obtained for ΔT=40°C with a corresponding Seebeck coefficient of 300 μV/K. A high conversion efficiency (ZT) requires conflicting properties of low thermal conductivity and low electrical resistivity. While this is conventionally difficult, metamaterials allow these two parameters to be decoupled. The monitoring system will be configurable for use with a wide range of instrumentation producing a deployable monitoring system powered with the new metamaterial technology. An asynchronous sensor device will be constructed based on the SSC patented monitoring technology incorporating a new energy harvesting circuit designed for use with the thermoelectric metamaterial prototype. The monitoring system technology is a highly power conservative monitoring system consisting of a base station and wireless sensor units. The sensors lay fully unpowered within a dormant state until they receive a trigger energy which consumes no stored power. The monitoring technology is capable of going completely powerless while allowing its unique power system to be charged by energy harvesting components, and the device is re-energized upon storing a sustainable amount of power. When activated, the sensor takes a measurement, transmits the data to the base station with a synchronized time stamp, and then returns to its dormant state. The monitoring system was primarily constructed as a torsional and linear strain sensor system potted in a hydrogen compatible material for Class 1 Division 2 environments, and the data tracking and archiving capabilities are beneficial in building operational and structural knowledge. By incorporating this system, the prototype energy harvester will be deployable within harsh ground propulsion environments. Additionally, the system could be utilized

in commercial applications that require long term monitoring of events associated with different types of strain, cryogenic temperatures, ambient temperatures, limit switches, milliamp signals, volt signals and magnetic fields.

Although this technology is designed to improve the monitoring of high-geared ball and linearly-actuated valves used in propulsion testing to predict valve life span and failure, it is not limited to use with only valves. It can monitor operational data, such as temperature in a particular location in a building, or the strain at a specific point on a bridge.

A single monitoring system will be capable of collecting transmitted data from both thermoelectrically powered sensor units for performing operational comparisons. To perform operational comparisons, one sensor unit will use the new one-of-a-kind thermoelectric metamaterial prototype, while a similarly constructed second sensor unit will use commercially available bismuth telluride thermoelectric thermal harvesting components for. The

Technology Transfer Program Logo

Table of Contents

Project Introduction	1
Anticipated Benefits	2
Organizational Responsibility	2
Project Management	2
Primary U.S. Work Locations and Key Partners	3
Technology Maturity (TRL)	3
Technology Areas	3
Images	4
Project Website:	4

thermoelectric metamaterial prototypes are currently fragile, and the integration of the prototype into the sensor system will ruggedize the components and make the unit a more robust device. This will allow the unproven technology to be operationally verified. A single monitoring system will be capable of collecting transmitted data from both thermoelectrically powered sensor units.

Anticipated Benefits

A deployable prototype monitoring system capable of being fully powered from thermal energy will benefit NASA funded missions by providing a maintenance free thermal energy harvesting system. Currently, this project is taking the prototype energy harvester and making it available for use within the harsh explosive environments throughout the SSC ground propulsion test facilities.

Benefits to NASA unfunded missions and planned missions of thermoelectric Metamaterial include use as a valid replacement for any other space based thermoelectric power generators, for example, like thermoelectrics used within nuclear space craft and planetary structures. This project has the potential to help Metamaterial energy harvesting develop into a proven technology with expectations that the technology will be incorporated for use throughout NASA and other space-based industries. Additionally, the material could feasibility enhance thermal energy harvesting for power generation and/or supplementation for large or small systems such as aircraft, space craft, uav and embedded instrumentation.

The Thermoelectric Metamaterial has potential benefits for the commercial space industry for any other space based thermoelectric power generators, like thermoelectrics used on satellites. This project has the potential to help utilization of Metamaterial energy harvesting so that this   technology can be further developed and potentially further adopted for use throughout space industries.

The thermoelectric Metamaterial is possible for utility for any other thermoelectric power generators/thermoelectrics used within other government agencies for example, with aircrafts, boats and submarines. Infusion of Metamaterial energy harvesting capabilities will help develop this technology for additional deployment options.

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Stennis Space Center (SSC)

Responsible Program:

Center Innovation Fund: SSC CIF

Project Management

Program Director:

Michael R Lapointe

Program Manager:

Ramona E Travis

Project Manager:

Scott L Jensen

Principal Investigator:

Scott L Jensen

Center Innovation Fund: SSC CIF

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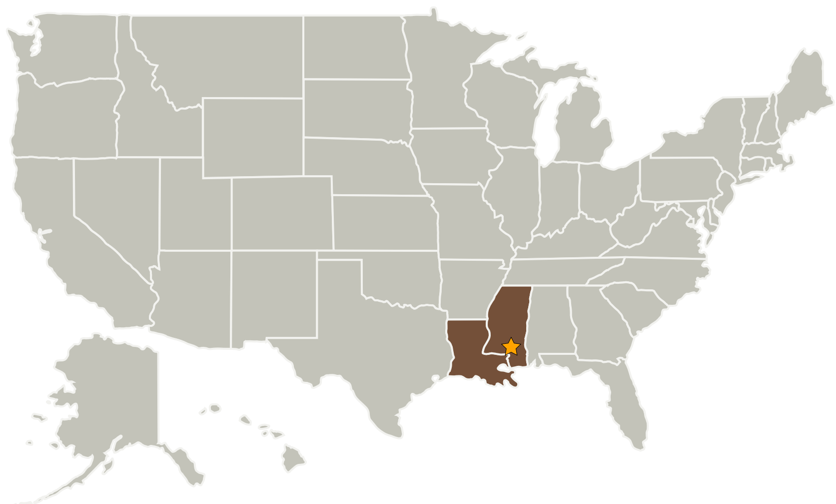
Primary U.S. Work Locations and Key Partners



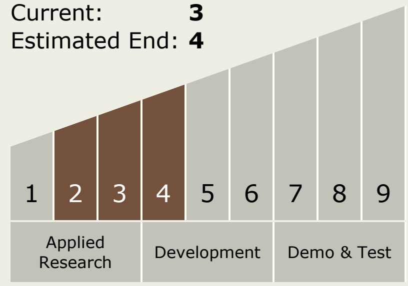
Organizations Performing Work	Role	Type	Location
★Stennis Space Center(SSC)	Lead Organization	NASA Center	Stennis Space Center, Mississippi

Co-Funding Partners	Type	Location
Loyola University New Orleans	Academia	New Orleans, Louisiana
University of New Orleans	Academia	New Orleans, Louisiana

Primary U.S. Work Locations	
Louisiana	Mississippi

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **4**



Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  - └ TX12.1 Materials
    - └ TX12.1.6 Materials for Electrical Power Generation, Energy Storage, Power Distribution and Electrical Machines

Images

Deployable Thermoelectric Metamaterial Energy Harvesting Monitoring System
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(https://techport.nasa.gov/image/16543)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html